IPCC WGIII Assessment Report: Chapter 6. Mitigation options in buildings

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IPCC WGIII Assessment Report: Chapter 6. Mitigation options in buildings

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Presentation outline

CO_2 emissions from energy use in buildings

- Importance of buildings sector
- Trends
- Scenarios
- Energy efficiency measures
- Potentials and costs
- Co-benefits
- Barriers
- Policies

Importance of the sector

- **Buildings-related emissions and their anticipated growth play a significant global role:**
  - **Energy use in the buildings sector was responsible for one-third of total global CO_2 emissions in 2004**
  - **This share could grow to 35-42% by 2030**
  - **Energy use in buildings will release to the atmosphere 11.8 to 15.6 Gt CO_2eq. in 2030, up from 8 Gt in 2004**

- **Measures to curb emissions in residential and commercial buildings need to be an integral part of a strategy to mitigate climate change**

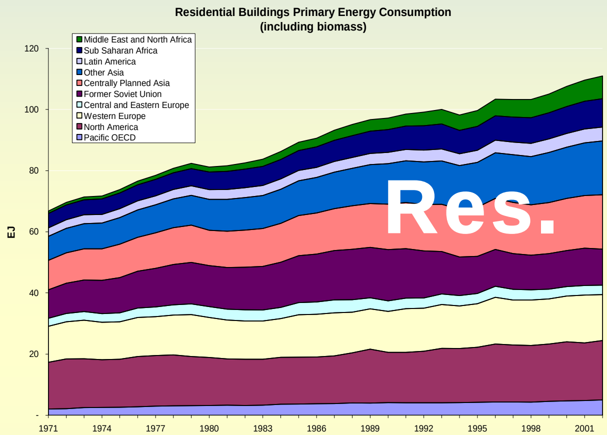
Reducing GHG emissions

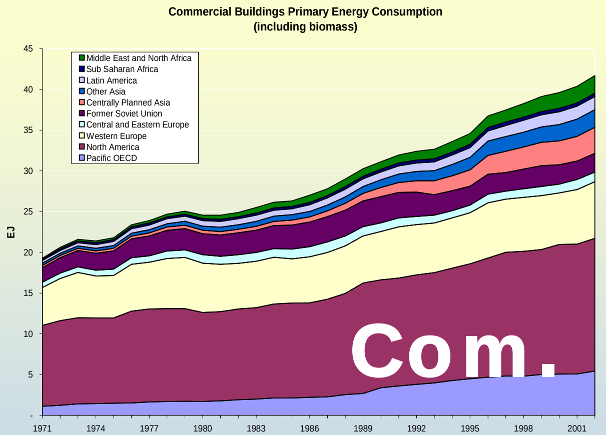
GHG emissions from buildings can be cut in 4 major ways

1. Reducing energy consumption in buildings
2. Switching to low-carbon fuels including a higher share of renewable energy (including decarbonizing electricity generation)
3. Controlling the emissions of non-CO2 GHGs
4. Reducing energy use of materials used for construction

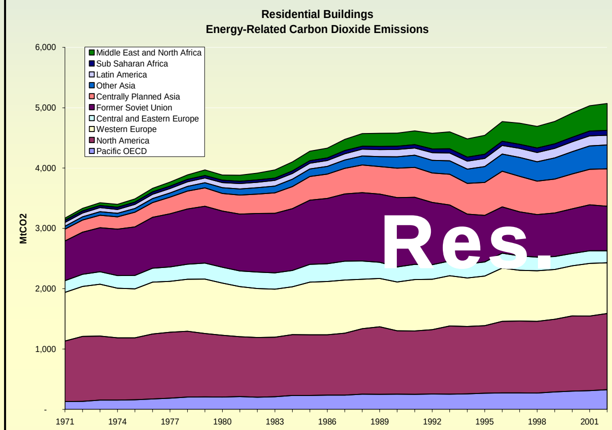
Energy and emission trends 1971-2002

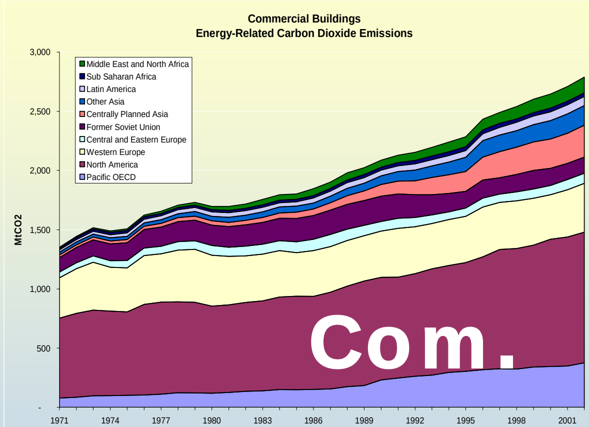
Energy Consumption





CO2 emissions





Energy use and CO2 emissions in buildings grew:

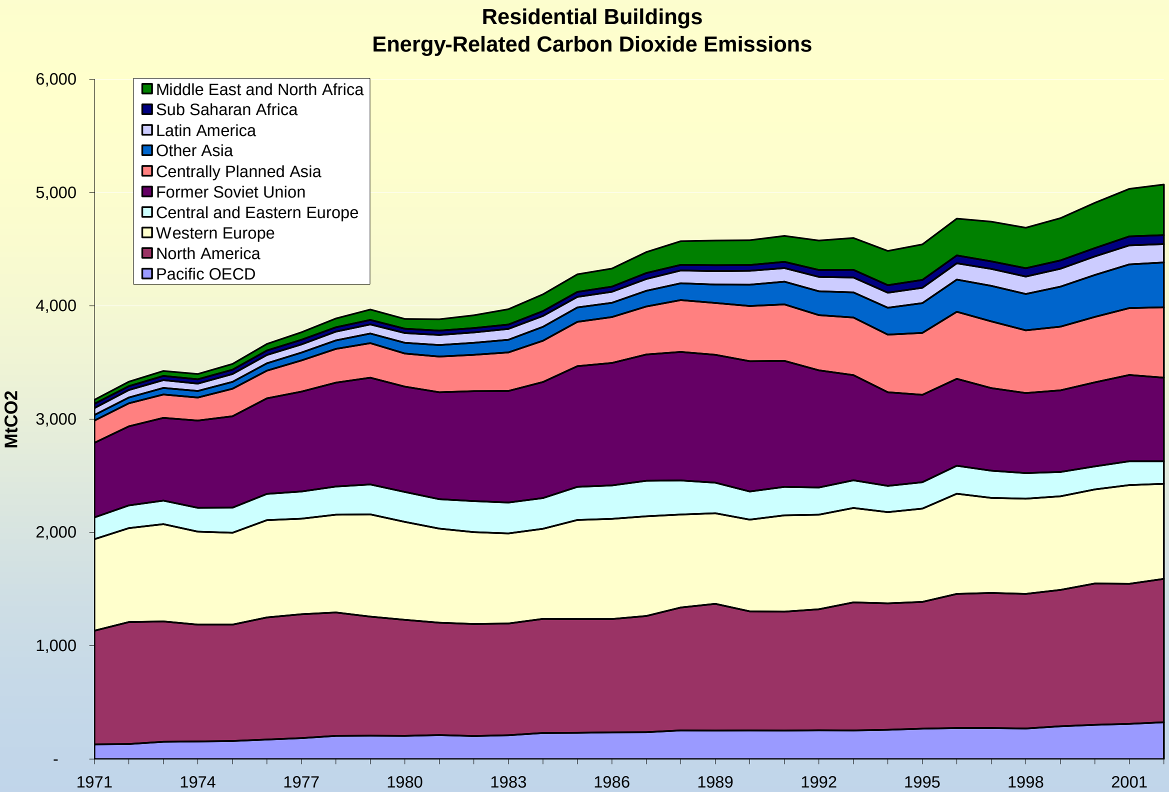
- **at ~ the same rate as other sectors**
- **much faster in commercial buildings than in residential**

Source for figures: Price et al., 2005

Emission trends in residential buildings

- Average annual growth rates of CO2 emissions were lower during the last 5 years than the 30-year trend (0.1% vs 1.4%)

CO2 Emissions from Residential Buildings (incl. biomass), 1971-2002.



- The largest increases in CO_2 emissions were:

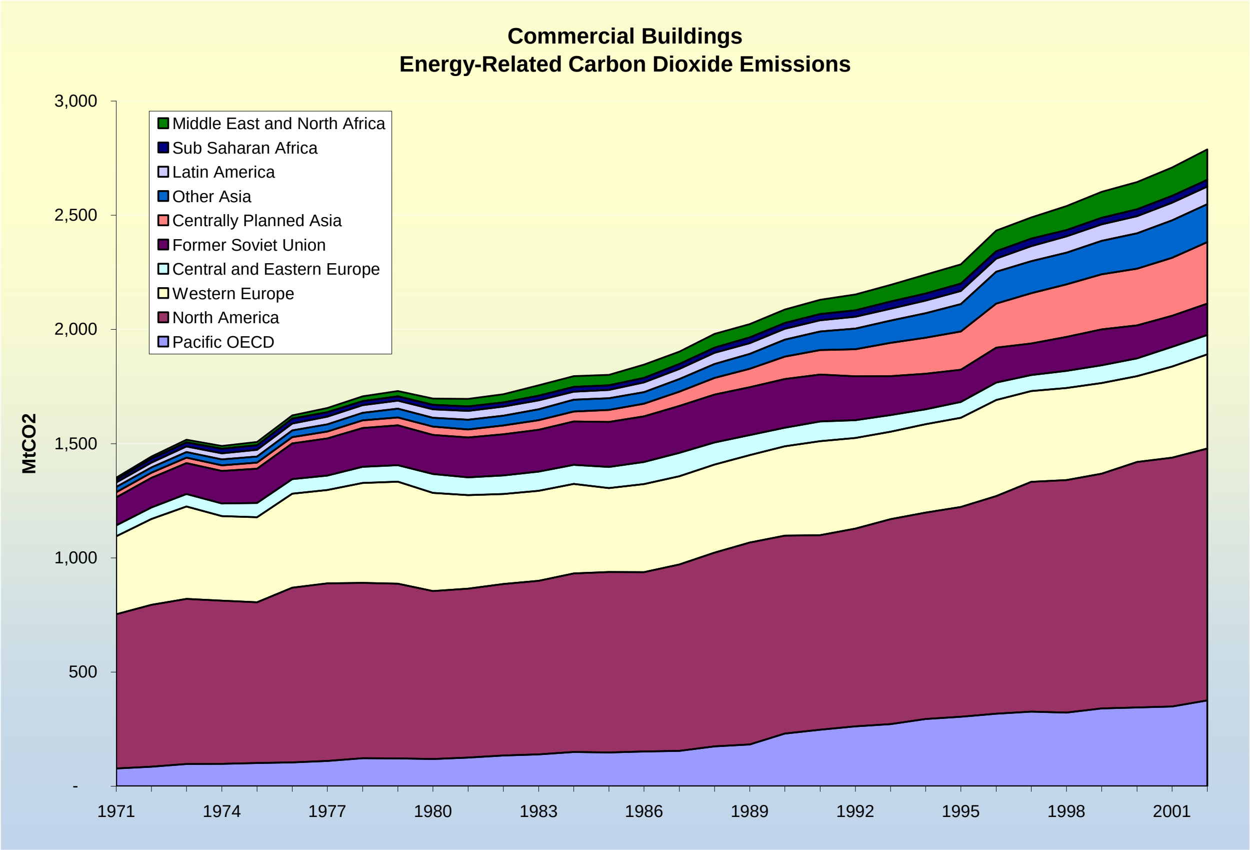
- China and India, 250 of the 500 MM t of CO_2 increase
- The Middle East/North Africa, 140/500
- North America, 70/500

Source: Price et al., 2005

Emission trends in comml buildings

- Average annual growth rates during the last 5 years were higher than the 30-year trend (3.0% vs 2.2%)

CO2 Emissions from Commercial Buildings (incl. biomass), 1971-2002



- The largest increases in CO_2 emissions were:

- North America, 125 of the 375 MM t of C increase
- China and India, 25/375
- OECD Pacific, 100/375

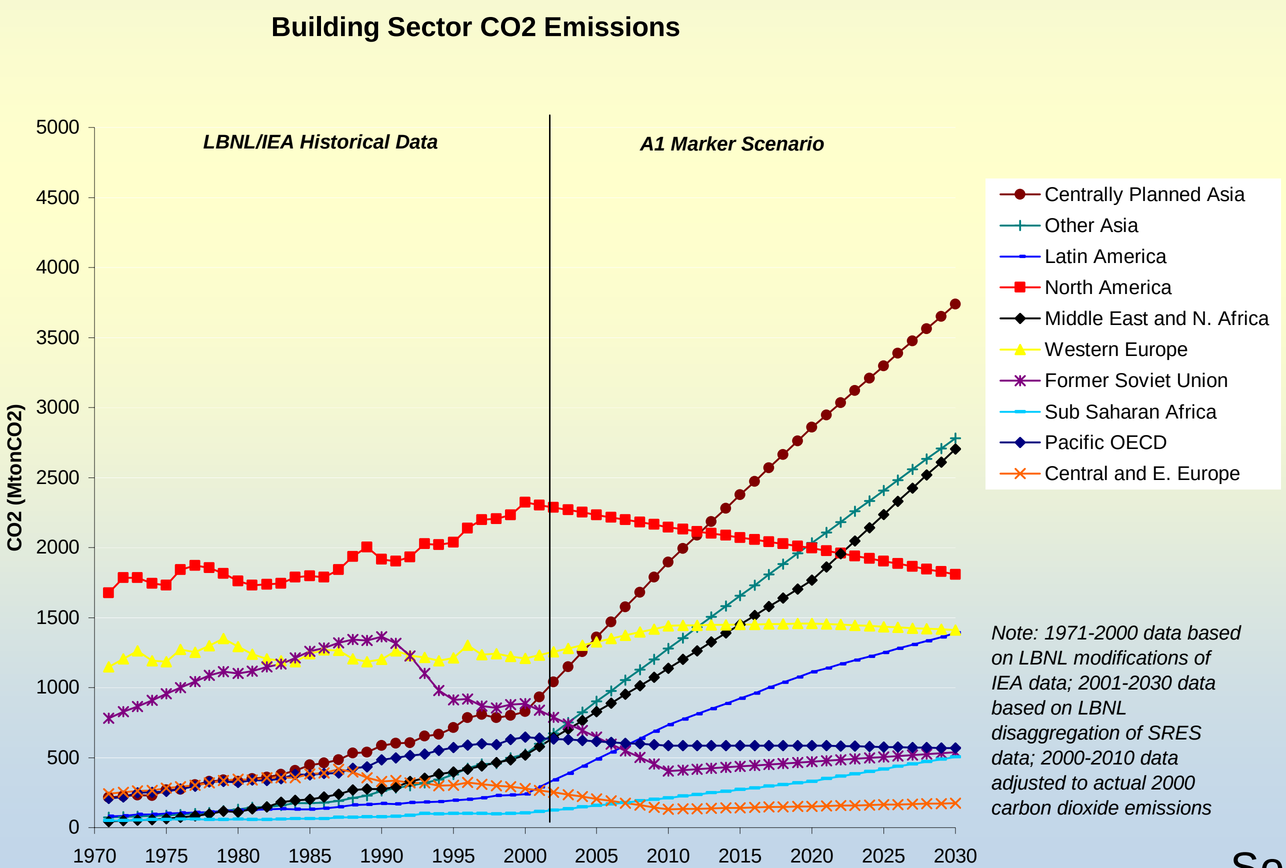
Source: Price et al., 2005

Factors for growth of energy and CO_2 emissions

- **For residential buildings:**
  - the largest driver is **advances in economic well being** in those developing countries that are increasingly able to grow their economies, and thus expand the building stock.
- **For commercial buildings:**
  - the most significant driver of increased energy demand is **expansion of commerce** and related activities (education, health care, recreation)

Projected CO2 emissions: A1 baseline scenario

- Shows **rapid economic growth**, especially in developing nations
  - **Most of CO2 emissions increase occurs in China, India, and Middle East / North Africa**

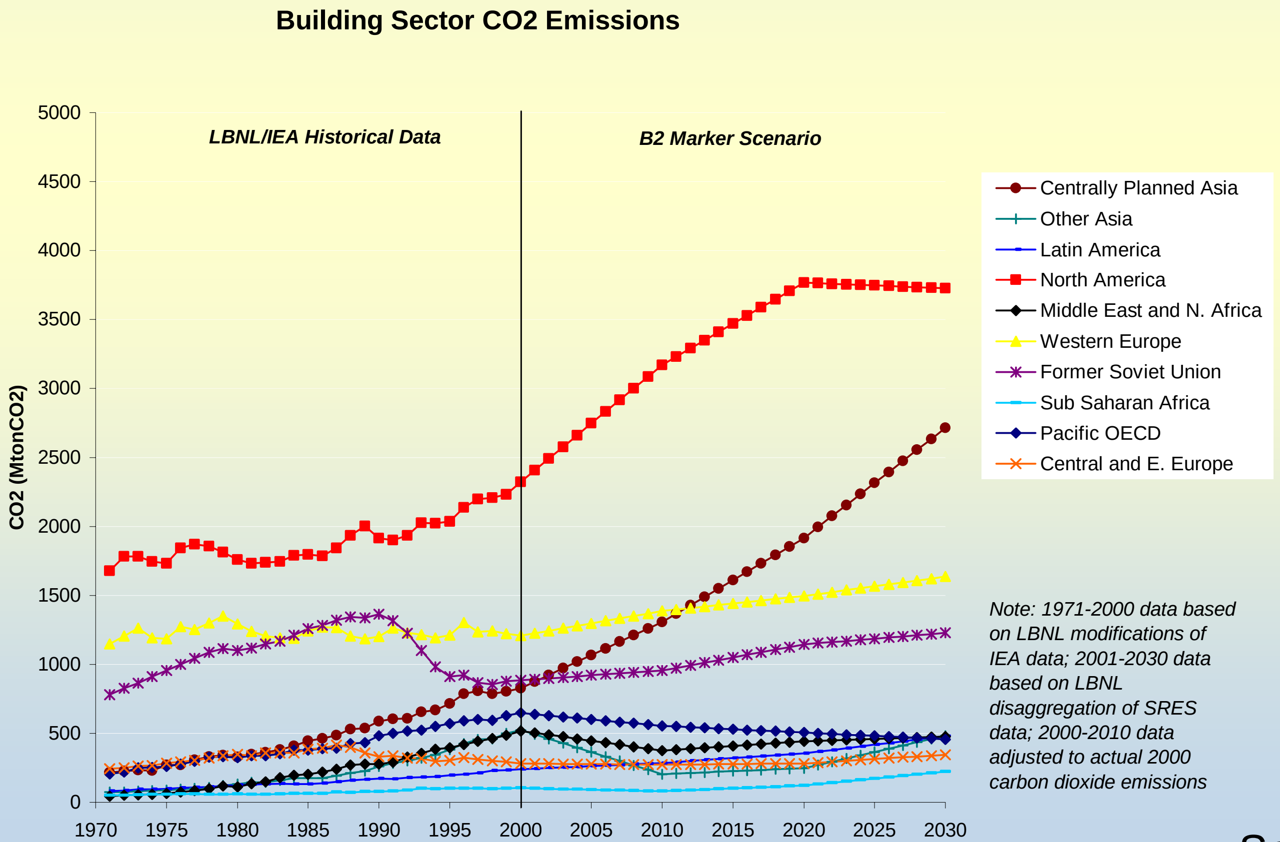


- **Projected CO2 emissions: 15.6 Gt in 2030**
- **Average annual CO2 emissions growth is 2.5% over the 30-year period**

Source: Price et al., 2005

Projected CO2 emissions: B2 baseline scenario

- Has **lower economic growth**, especially in the developing world (except China)
  - 2 regions account for the largest portion of increased CO2 em. in 2000-2030: **China and North America**



- Projected CO2 emissions: **11.8 Gt in 2030**
- Average annual CO2 emissions growth is **1.5% over the 30-year period**

Source: Price et al., 2005

Overview of energy efficiency principles

- Reduce heating and cooling loads (insulation, window shadings)
- Increase efficacy of lighting equipment and control usage
- Increase efficiency of appliances, heating and cooling equipment and ventilation
- Utilize active solar energy and other environmental heat sources and sinks
- Implement commissioning and improve operations and maintenance
- Change behavior
- Systems approach to energy efficiency

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Assessment of mitigation technologies and practices

- **The largest savings in energy** use **for new commercial buildings** (as high as 50-75%) arise **through designing** and operating buildings **as complete systems**
- **Over the whole building stock a large portion of carbon savings** by 2030 is **in retrofitting existing buildings and replacing energy-using equipment** with more advanced low-energy alternatives

E.E. measures: thermal envelope 1

- **Thermal envelope**
  - **Improvements in the thermal envelope can reduce heating needs by 2-4 times at little to no net incremental cost**
  - **Advanced houses use 10% of the heating energy of houses built according to the local national building code**
  - **Reducing the envelope heat loss by 2 reduces the heating requirements by > than 2 due internal heat gains from equipment, occupants, and lighting**

Sources: Demirbilek *et al.*, 2000; Hamada and al., 2003; Hastings, 2004; Badescu and Sicre, 2003; Hamada and al., 2003; Hastings, 2004, Harvey, 2005b.

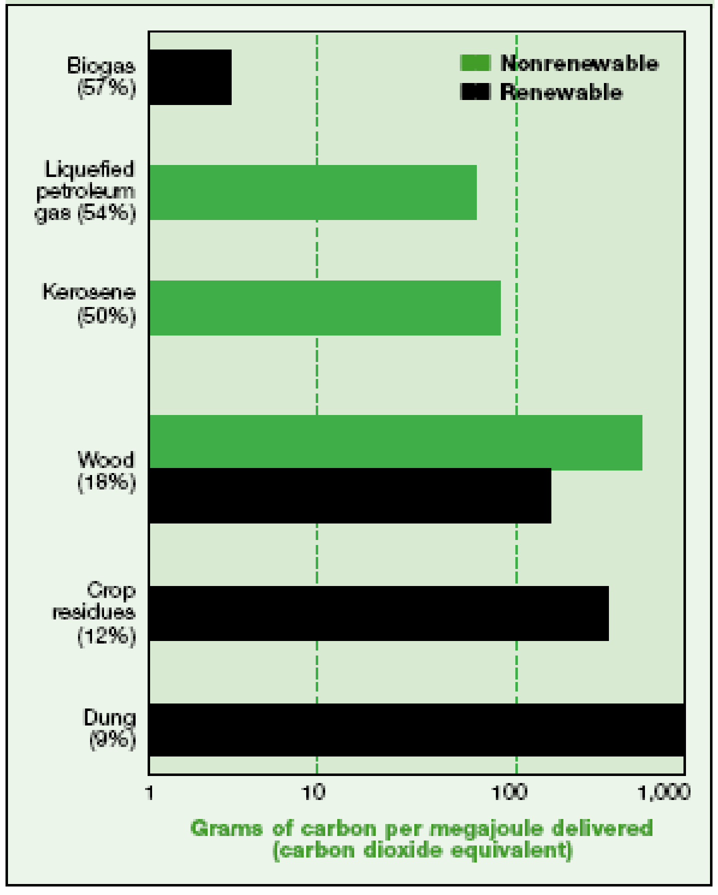
E.E. measures: thermal envelope 2

- The effectiveness of the thermal envelope depends on:
  - The insulation levels in the walls, ceiling, and basement floor and the thermal properties of windows and doors
  - The absorptive, reflective, and transmissive properties of windows
    - Shading devices
    - Multiple glazing layers, low-emissivity coatings
    - Spectrally selective windows
    - Electrochromic and thermochromic glazing
  - The rate of exchange of inside and outside air
    - In cold climates, air leakage can cause >1/2 of heat loss
    - In residences, infiltration barrier can reduce rates of air leakage by a factor of 5-10
    - Aeroseal, a technology in early commercial use in US, seals duct leaks by spraying fine particles into ducts

Sources: Demirbilek *et al.*, 2000; Hamada and al., 2003; Hastings, 2004; Badescu and Sicre, 2003; Hamada and al., 2003; Hastings, 2004, Harvey, 2005b.

E.E. measures: heating systems

- ➢ **Passive solar heating**
  - **Envelope measures + passive solar heating have achieved heating energy reductions by factors of 5-30**



- ➢ **Coal and biomass burning stoves in rural areas of developing countries**
  - **3 billion people use biomass and coal in household stoves to meet cooking, water & space heating needs**
  - **Most stoves are of inefficient and highly polluting designs**
  - **In the long term, stoves that use biogas or biomass-derived liquid fuels offer the greatest potential**

Sources: Krapmeier and Drössler, 2001; Gauzin-Müller, 2002; Kostengünstige Passivhäuser als europäische Standards, 2005.

E.E. measures: cooling

- **Reduce cooling loads**
  - Orient a building to minimize the east and west-facing walls
  - Cluster buildings to provide self shading
  - Use high-reflectivity building materials
  - Provide fixed or adjustable shading
  - Use windows with a low solar heat gain
  - Utilize thermal mass to minimize daytime interior temperature peaks
  - Increase roof albedo
- **Use passive techniques to meet some or all of the load**
  - Natural ventilation
  - Night-time ventilation
  - Evaporative cooling
  - Underground earth-pipe cooling
- **Improve the efficiency of cooling equipment and thermal distribution systems**
  - High efficiency air conditioners and vapor-compression chillers
  - Absorption chillers and cogeneration

Source: Rosenfeld et al., 1998

E.E. measures: HVAC systems

- **Principles of energy-efficient HVAC system**
  - Minimize simultaneous heating and cooling (eliminate reheat)
  - Use Variable-air volume (VAV) systems to reduce fan and pump power
  - Separate the ventilation and dehumidification from the heating / cooling by using water for temperature control and just enough air for ventilation / dehumidication
  - Allow the temperature maintained by the HVAC system to vary seasonally with outdoor conditions
- **Application of HVAC alternatives that together can reduce the HVAC system energy use by 50-75%**
  - Radiant chilled ceiling cooling
  - Displacement ventilation
  - Desiccant dehumidification and cooling
  - Advanced control systems with diagnosis and feedback

Source: Kintner-Meyer and Emery, 1995; Henze, 2003.

E.E. measures: lighting and daylighting

- **Lighting energy use can be reduced by 50-90% through:**
  - **Use of daylighting with sensors and controls**
  - **Use of the most efficient lighting devices available**
  - **Use of ambient / task lighting**
- **Daylighting techniques include:**
  - **Light shelves**
  - **Prismatic panels, light-directing louvers, and laser-cut panels**
  - **Anidolic ceilings, which collect light under overcast conditions and redirect it into the room over a narrower angular range**

Source: Banwell et al, 2004, Rubinshtein and Johnson, 1998; jennings et al, 2000, Bodart and Herde, 2002, Reinhart, 2002, Atif and galasiu, 2003, Li and Lam 2003

Energy efficiency in buildings:
What are emerging areas for E-saving?

- **Commercial buildings:**
  - Controls and information technology to continuously monitor, diagnose, and communicate faults in commercial buildings
  - Systems approaches to reduce the need for ventilation, cooling, and dehumidification
- **Residential buildings:**
  - Advanced windows, passive solar design, techniques for eliminating leaks in buildings and ducts, and very energy efficient appliances
- **Both residential and commercial sectors:**
  - Controlling standby and idle power consumption, solid-state lighting
- **+ALSO!:**
  - Increasing climate change literacy and consumer access to useful information to improve occupant behavior as a major determinant of energy use and CO2 emissions

Potentials for GHG mitigation in buildings worldwide

- The Chapter updated the assessment made in TAR
- Review included 56 recent studies from 32 countries and 10 country groups, spanning five continents
- Estimates of technical potential range:
  - From 18% of year 2020 buildings-related CO_2 emissions in Pakistan with only a limited number of options
  - To 99% in South Africa with also supply-side measures such as switching entirely to green electricity
- The estimates cost-effective potential vary:
  - From 14% of residential emissions in Canada
    to 37% for all US buildings and 41% for buildings in Brazil
- The market potential was projected for the case of China at 23% of residential and commercial emissions

Estimate of global potential for GHG mitigation in buildings

- The estimate for the global potential was suggested based on 11 studies (that included economics in their analysis) from countries in 4 continents:
  - By 2020, globally 1500 and 900 million tons of CO_2eq. can be avoided annually through energy efficiency in the residential and commercial sectors respectively
  - This is 23% of the BAU emissions for all buildings in 2020 using the B1 Scenario as baseline.
- Due to the limited number of demand side end-use efficiency options considered by studies, the real potential is likely to be higher
- These figures are similar to those reported in the TAR for 2010, indicating the dynamics of GHG reduction opportunities

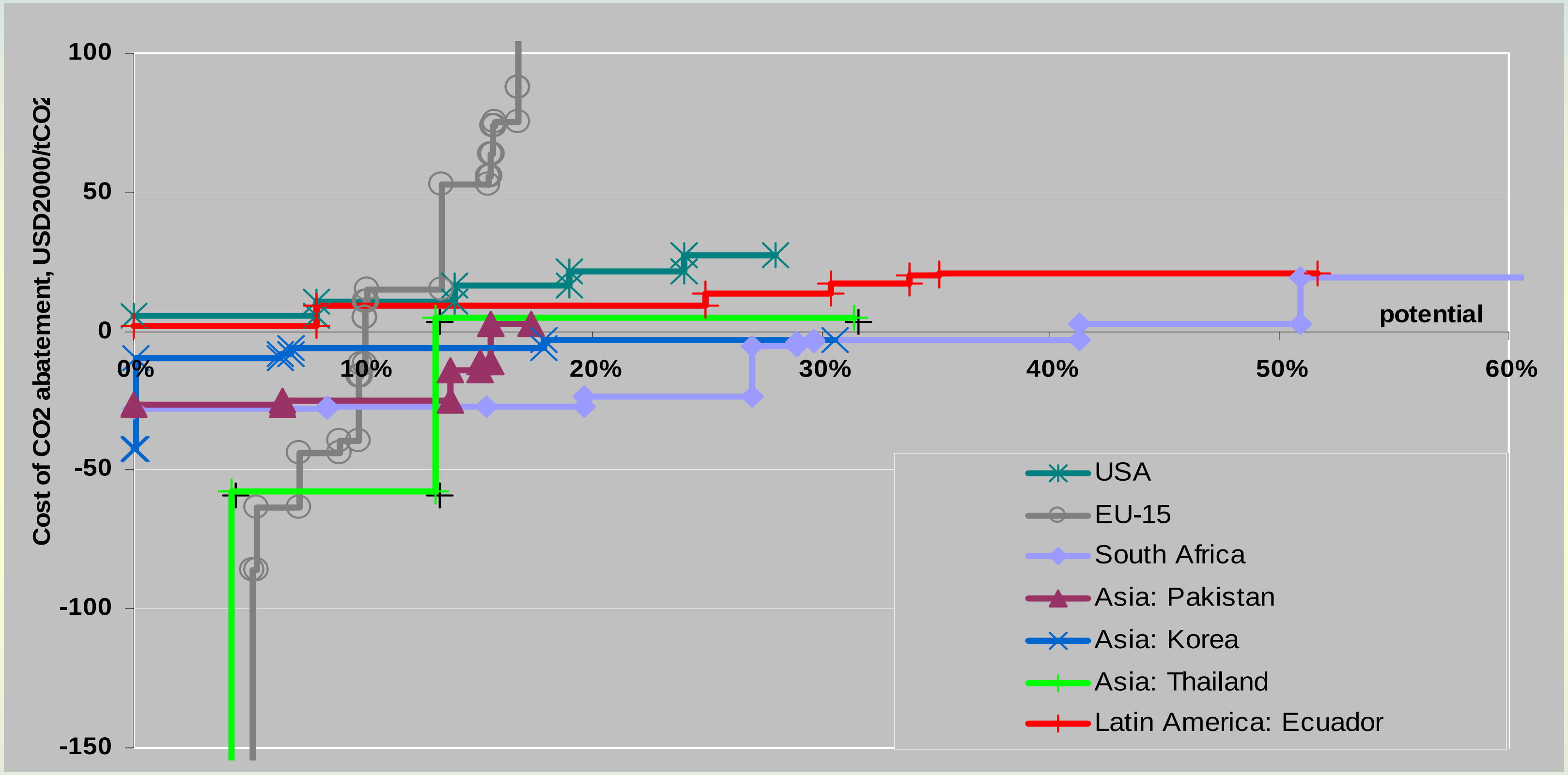
Costs of GHG Mitigation in Buildings

- **Only a few of the studies also detail the associated costs**
- **Results of different studies – even for the same country – vary considerably depending on input assumptions**
- **To be captured at negative cost (net benefit):**
  - **up to 41% of GHG emissions in developing countries and CIT**
    - **Thailand, Republic of Korea, Pakistan, South Africa, China, India, Indonesia, Russia, Brazil, Argentine**
  - **11–25% in developed countries**
    - **EU-15, Japan, Canada, New Zealand, Australia, Greece**
- **At costs up to US$25/tCO2eq.:**
  - **17%-85% in developing countries and CIT**
    - **Ecuador, Thailand, Republic of Korea, Pakistan, South Africa, Hungary**
  - **14%-28% in developed countries***
    - **EU-15**

*** Or up to 58% savings including a single study for Hungary**

Sources: ADB 1998c, ADB 1998d, ADB 1998k, De Villers and Matibe 2000, Joosen and Blok 2001, FEDEMA 1999, APEIS 2004, Mirasgedis et al 2003, Urge-Vorsatz and Szlavik 1999, FEDEMA 1999.

Supply curves of conserved CO2 for buildings in 2020*



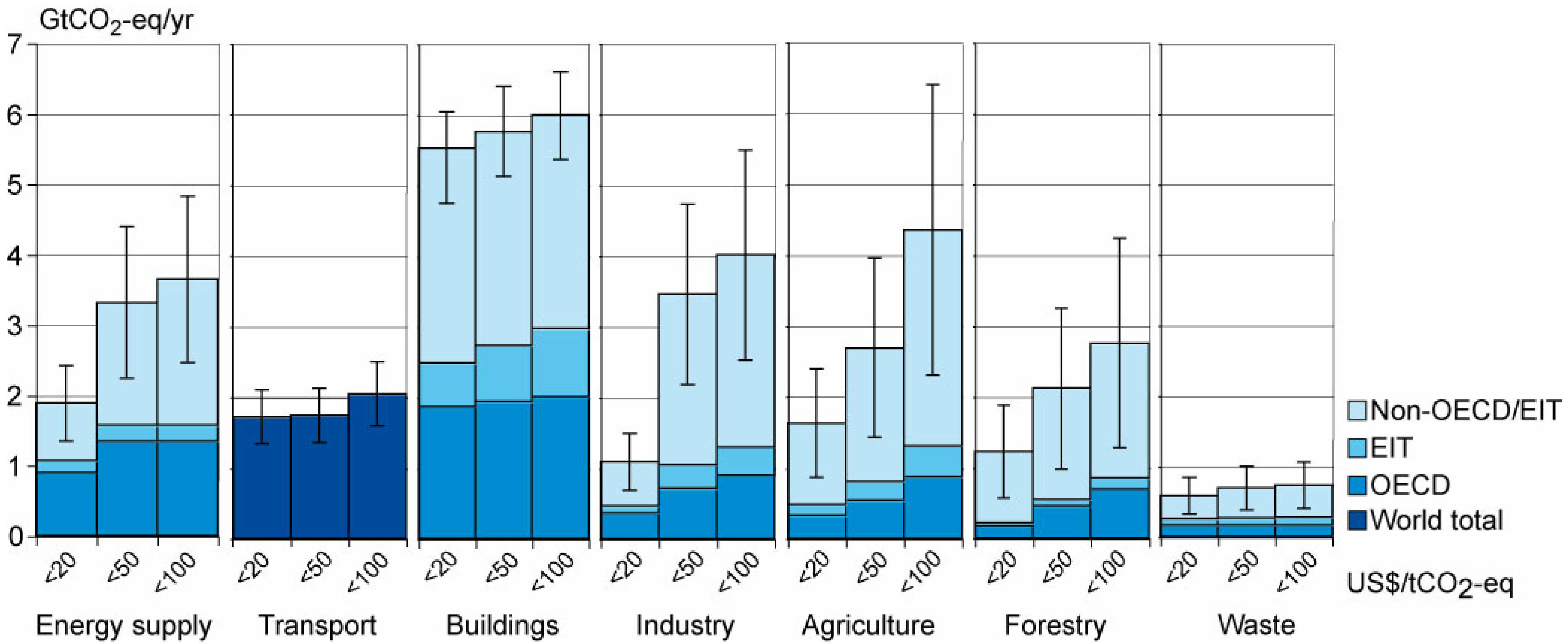
***Except for Ecuador and South Africa, for which the target year is 2030.**

Sources: Joosen and Blok 2001, Newell and Pizer 2005, ADB 1998a, ADB 1998b, ADB 1998c, De Villers and Matibe 2000, FEDEMA 1999.

Challenges and limitations

- Methodological challenges: studies use a variety of assumptions and analytical methods
- Small number of studies
- Results for distant future years (2020 and 2030) necessarily uncertain
- Conflicting views about meaning of results – economic potential

All Sectors and Regions have potential to contribute to CC mitigation



Note: estimates do not include non-technical options, such as lifestyle changes.

WMO UNEP

Co-benefits of GHG Mitigation

1. Reduction in regional air pollution
2. Energy security
3. Improved quality of life and comfort
4. Improved productivity and economic competitiveness
5. Employment and business opportunities
6. Improved social welfare

Co-benefits of GHG mitigation

1. Reduction in regional air pollution

- **Especially SO_2, NO_x, VOC, and particulate matter emissions;** their main impacts are:
  - **increased deaths and morbidity,**
  - **damage to forests, ecosystems, and agriculture**
  - **deterioration of buildings and historical monuments**
  - **Note: in 2000, 3 million life-years – equivalent to about 288,000 premature deaths – were lost in the EU due to particulate pollution; the numbers are much higher in China with high pollution in large cities**

2. Energy security

- **Reduced energy imports**

Source for data: European Commission, 2005

Co-benefits of GHG Mitigation

3. Improved quality of life and comfort

- **Improved thermal comfort**
  - Fewer cold surfaces such as windows
- **Reduced level of outdoor noise infiltration and indoor pollution from outdoors**
  - Triple glazed windows or high-performance wall & roof insulation

Note: the value of these co-benefits may amount to the same order of magnitude as the economic value of E-savings

Case study of the tourism sector

- Tourism has a high economic value for national income; tourist accommodation can consume a lot of energy
- Numerous measures are available, often at low or no cost, to reduce energy waste and hence cut CO2 emissions
- Almost all these measures improve comfort and reduce operating costs, therefore enabling hoteliers to offer increased amenities

Co-benefits of GHG Mitigation

4. **Improved productivity and economic competitiveness**

- **Direct effect**
  - High quality, energy-efficient space conditioning and lighting enhance employee productivity and can increase sales in retail environments
- **International competitiveness**
  - For commercial office buildings cutting energy use (and energy costs) by 30% will yield the same bottom-line benefits a 5% increase in net operating income
- **Shareholders value**
  - The added market value of good energy management is an indicator of overall management quality

Source for data: GreenBiz, 2005; Makower, 2005.

Co-benefits of GHG Mitigation

5. Employment and business opportunities

- ❖ Providing **energy efficiency services** has proven to be a lucrative business opportunity
  - – Experts estimate the ESCO market as $7-15 billion in Europe; probably higher in the United States

6. Improved social welfare

- ❖ Reduction of **fuel poverty**
  - - especially in former communist countries where energy subsidies have been removed

  Note: Fuel poverty is the inability to afford basic energy services to meet minimal needs or comfort standards,
  - – in 1996, ~ 4.3 million UK households (~20%) lived in fuel poverty (>10% of income for energy services)

Sources for data: Jochem and Madlener 2003, European Commission 2005, Butson, 1998.

Market barriers to energy efficiency

1. **Traditional building design process**
2. **Fragmented market structure**
3. **High transaction costs to find efficient products**
4. **Misplaced incentives and administrative hurdles**
5. **Energy subsidies, non-payments and theft**
6. **Small project size, transaction costs and perceived risk**
7. **Imperfect information**
8. **Power quality and electronics**
9. **Other barriers:** limited availability of energy-efficient equipment, limited access of low-income households and small business to capital markets, inadequate levels of energy services, and others

Market barriers to energy efficiency

1. **Limitations of the traditional building design process:**
   - **Minimizing energy use requires optimizing the system as a whole**
   - **In contrast, the typical design process is linear and sequential**
   - **Integrated design process (IDP) helps to achieve 35-50% energy savings at little to no incremental upfront cost**
2. **Fragmented market structure**
   - **Builders, designers, engineers and suppliers often work at cross purposes and rarely have seamless communication needed to advance state of the art of energy efficiency**
3. **High transaction costs**
   - **Difficult and costly to find/identify/verify energy efficient equipment, materials and practices**

Sources for data and facts: Harvey 2006; Coleman, 2004

Market barriers to energy efficiency

4. **Misplaced incentives and administrative hurdles**
   - **Landlords provide appliances, while tenants pays the electricity bill**
   - **Operating expenses and investments (in energy efficiency) for public hospitals and schools are often from completely different sources of money**
   - **For government entities projects must often be awarded to the lowest-first-cost design**

5. **Energy subsidies, non-payment and theft**
   - **Electricity price subsidies hinder the penetration of energy-efficient technologies**
     - **In developing countries, in CEE and the FSU due to fuel poverty**
   - **After tariff increases, non-payment became a serious issue**
     - **In the late 1990s collection rates in Albania, Armenia, and Georgia were ~ 60% of billings**
   - **Electricity theft occurs at a large scale**
     - **Distribution losses due to theft are ~ 50% in some states in India**
     - **Electricity theft in USA costs utilities billions of dollars each year**

Sources for data and facts: Rezessy *et al.* 2006, Jones, *et al.*, 2002; Lovins, 1992; Gritsevich, 2000; World Bank, 1999; Suriyamongkol, 2002; EIA, 2004; Suriyamongkol 2002.

Market barriers to energy efficiency

6. **Small project size, transaction costs and perceived risk**
   - Energy efficiency projects are typically small; major financial institutions have little interest in such small projects
   - Asset-based lending practices, a limited understanding of energy efficiency technologies, volatile fuel prices, and non-diversified portfolios of projects increase perception of market and technology risk
7. **Imperfect information**
   - Information about energy efficiency is often incomplete, unavailable, expensive
   - The benefits are generally not directly observable
   - Discount rates often very high, disfavoring investments in energy efficiiency

Sources for data and facts: Alderfer, et al., 2000; U.S. DoE, 2003.

Market barriers to energy efficiency

8. **Power quality and electronics**
   - **Several energy-efficient technologies place high requirements on power quality**
     - **For example, in many developing countries CFLs, electronic ballasts, variable speed motors and other equipment may not function properly, or may fail, if the power quality is compromised**
     - **This is one of the top barriers to adopting energy efficiency in India**

9. **Other barriers include:**
   - **The limited availability of energy-efficient equipment along the retail chain**
   - **The limited access of low-income households and small businesses to capital markets**

Sources for data and facts: EAP UNDP, 2000; Brown, Berry, and Goel, 1993.

Experiences with climate change policies: typology of policy tools

➢ **Many different policy instruments have been tried**

Control and regulatory mechanisms	Fiscal instruments and incentives	Economic and market-based mechanisms	Support, information and voluntary action
➢'Direct' regulation: technology standards, performance standards, building codes, emission standards, permits, bans, usage restrictions; ➢Public budgeting and public procurement rules; ➢Obligations to achieve certain outcomes: energy saving quotas, spending on energy efficiency; ➢Revenue regulation and billing regulation; ➢Demand-side management.	➢Taxation; ➢Recycling energy tax revenue; ➢Tax exemptions and reductions; ➢Cost recovery mechanisms for energy efficiency programs; ➢Public benefit charges; ➢Capital subsidies, grants and rebates, low-interest loans, lower interest rates, and loan guarantees.	➢Energy performance contracting; ➢Energy outsourcing; ➢Co-operative procurement for energy efficient appliances and equipment; ➢Emission trading schemes (cap-and-trade, baseline-and-credit); ➢Tradable green and white certificates;	➢Energy performance labellng and certification (appliances, cars, buildings); ➢Awareness raising campaigns, education and training; ➢Energy audit programs; ➢Communicating pricing and other information for energy efficiency; ➢Energy efficiency branding; ➢Voluntary agreements (a.k.a. negotiated agreements).

Experience with Policies Worldwide

1. **Policies and programs aimed at construction, retrofit, and installed equipment and systems**
   - Buildings codes
   - Building certification and labeling systems
   - Education and trainings
   - Energy audit programs
   - Financial incentives
   - Policies aimed at the energy improvement of existing buildings
2. **Policies and programs aimed at appliances, lighting, and office / consumer plug loads**
   - Standards and labeling
   - Voluntary agreements
3. **Policies affecting fuel switching – renewable and nuclear electricity supply**
4. **Policies affecting technology transfer to developing countries including CDM and JI**

Experience with Policies Worldwide

5. Cross-cutting policies and programs that support energy efficiency and/or CO_2 mitigation in buildings
   - Energy prices, subsidies and taxes
   - Investment schemes and fiscal measures
   - Energy efficiency obligations and tradable certificates
   - Research and development
   - Public sector leadership programs including public buildings and government procurements
   - Promotion of ESCOs and energy performance contracting
6. Electric and Gas Utility Demand-Side Management
   - For example, California now has $2B DSM program over three years
7. Policies affecting non-CO_2 gases
   - Stationary refrigeration, air conditioning, and heat pumps
   - Insulating foams

Example of energy subsidies

- The bulk of subsidies in developing and CIT are paid to consumers (~60% of non-OECD energy demand or ~US$95 billion 1998
- Producer subsidies are most common in industrialized countries
- Removing subsidies in 8 countries shown on next viewgraph reduces energy use by 13% and CO_2 emissions by 16% and raises GDP by ~ 1%

Sources: IEA, 1999; UNEP OECD/IEA, 2002; Markandya, 2000.

Energy subsidies

Country	Av. rate of subsidy removed (% of market P)	Annual ec. efficiency gain (% of GDP)	Reduction in energy use(%)	Reduction in CO_2 em. (%)
China	11	0.4	9	13
Russia	33	1.5	18	17
India	14	0.3	7	14
Indonesia	28	0.2	7	11
Iran	80	2.2	48	49
South Africa	6	0.1	6	8
Venezuela	58	1.2	25	26
Kazakhstan	18	1.0	19	23
Total	21	0.7	13	16
Total world	**n.a.**	**n.a.**	**3.5**	**4.6**

Sources: IEA, 1999; UNEP OECD/IEA, 2002; Markandya, 2000.

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Examples of investment incentives and fiscal measures

- Many developed countries offer incentives for energy efficiency measures
- Different instruments -- subsidies, tax reduction schemes, and preferential loans – are used in different countries
  - **Energy policies in countries with a cold or moderate climate concentrate on the retrofit of existing buildings**
  - **Several countries combine them with al policy to assist low-income households (US, Fr, UK, etc)**
  - **Financial incentives for energy efficient appliances are in place in a limited number of countries (US, Belgium, Canada, Denmark, Japan, Germany, Netherlands)**
- Table (IEA 2004c) on the next 3 slides presents an overview of selected financial support measures on climate change policy

Examples of financial support measures for sustainable buildings, in several OECD countries

Country	Program Title	Fiscal measure	Techniques
Austria	Federal Environmental Fund	Subsidy	-Biomass and biogas district heating - Energy efficiency measures -Thermal renovations of entrepreneurial buildings
Belgium	Tax Reduction for Home Improvement – Federal	Tax Reduction	-Replacement of old boilers by new condensation boilers - Installation of double glazing, roof insulation, the installation of a central heating regulator, plus energy audits
Belgium	Subsidies to Improve Energy Efficiency in Buildings – Wallonia & Brussels-Capital	Subsidy	- Energy audits in buildings - Energy efficiency improvements low-income households
Canada	Commercial Building Incentive Program (Extension)	Subsidy	- New commercial and institutional buildings that are designed to be at least 25% more energy efficient that building standard
Canada	EnerGuide for Houses Retrofit Incentive	Subsidy	- Personal energy evaluation and retrofit plans to homeowners to encourage them to implement energy efficiency retrofits
Canada	Energy Innovators Plus (Extension)	Subsidy	- Energy efficiency retrofits of commercial and institutional buildings - Refrigeration and equipment

Examples of financial support measures for sustainable buildings, in several OECD countries

Country	Program Title	Fiscal measure	Techniques
Canada	Power Smart New Home Program in British Columbia	Subsidy	- Energy efficiency technologies in new houses
France	Tax credit in favor of high efficiency natural gas boilers	Tax reduction	- High efficient natural gas boiler
France	Extension of Tax Credit for Large Collective Equipment, Renewable Energy Equipment, Thermal Insulation and Heating Regulation Equipment	Tax reduction	- Thermal insulation and regulation material
Germany	CO2 Building Modernization Program	Preferential Loan	- Raise energy efficiency of 30 000 units of existing stock of residential buildings
Germany	Renewable Energy Promotion Programme	Subsidy	-Thermal solar collectors -Energy conservation measures
Ireland	House of Tomorrow Programme	Subsidy	- Research, development, and demonstration projects to achieve more sustainable energy in new and existing houses
Japan	Home Energy Management System, Building Energy Management System	Subsidy	- Energy management systems in homes and buildings

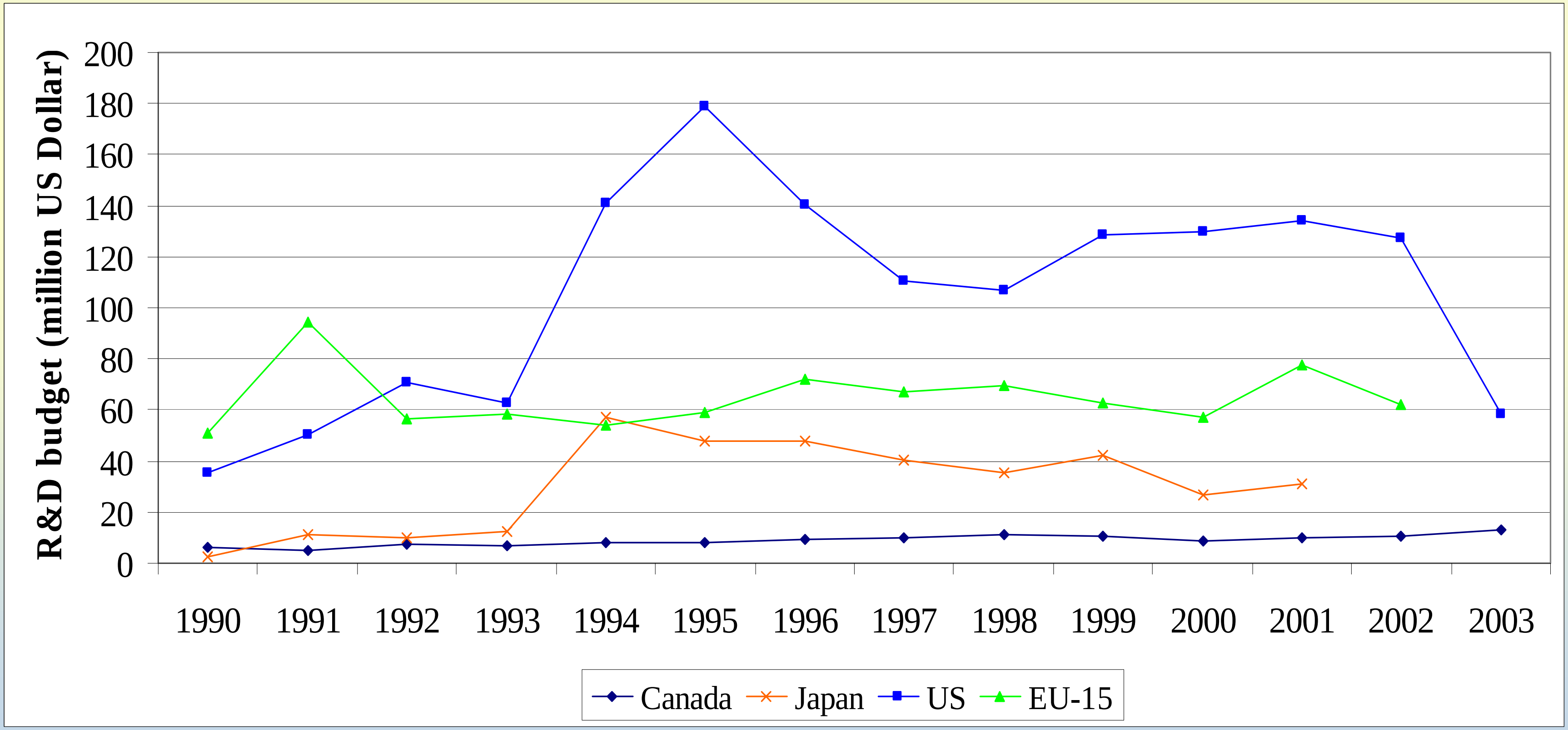
Examples of financial support measures for sustainable buildings in several OECD countries

Country	Program Title	Fiscal measure	Techniques
The Netherlands	Energy Premium Regulation	Subsidy	- Energy conservation measures and purchase of energy efficient appliances by households
United Kingdom	Energy Efficiency Commitment	Subsidy	- Domestic energy efficient improvements, insulation, energy efficient boilers, appliances and lights bulbs (focus on low-income consumers)
United States	Grants to Improve Energy Efficiency of Low-Income Households – Weatherization Assistance Program 2001	Subsidy	- Energy efficient services for low income households that include installating insulation and ventilation fans sealing ducts, adding weathers stripping, and insulating water heating systems
United States	Tax Incentive Package – Federal level	Tax reduction	-Energy efficient new homes -Energy efficient products
United States	Energy savings Performance Contracts	Preferential funds	New energy efficient equipment

Need for technology RD&D

- Since 1996, the annual worldwide RD&D budget for energy efficiency in buildings has been only ~ US$225-280 million
- US is responsible for 1/2 of this total global expenditures

Annual budget for R&D in energy conservation in the residential and commercial sectors in 1990-2003



Source: IEA, 2004c

Conclusion 1

- **Projections shows the growing role of the building sector**
- **According to Scenario A1 (leading to high energy growth)**
  - **Average annual energy growth (AAGR) in buildings is 2.5% in 2000-30**
  - **Even with potential cost-effective energy savings, energy use in buildings would continue to grow at ~1.5% during the period**
- **For Scenario B2**
  - **AAGR in buildings is 1.5%**
  - **AAGR could be reduced to can ~0.5% with cost-effective energy efficiency**
- **A tax on CO_2 would contribute substantially to reductions in growth of energy and CO_2 emissions**

Conclusion 2

- The savings may be difficult to achieve in the real world
  - **There is no assurance that the policies will be enacted**
  - **Even if they were, slow turnover of buildings and larger, installed equipment would delay some fraction of the savings**
  - **New uses for energy and larger buildings may offset the reduction in energy use**
- The largest savings in energy use for new buildings (50-75%) arise through designing and operating buildings as complete systems (an integrated design process)
- Over the whole building stock a large portion of CO_2 savings by 2030 is in retrofitting existing buildings and replacing energy-using equipment with low-energy alternatives

Conclusion 3

- **Emerging areas for energy savings in commercial buildings:**
  - **Controls and information technologies**
  - **Systems approaches to reduce the need for ventilation, cooling, and dehumidification**
- **In residential buildings, emerging areas are:**
  - **Advanced windows, passive solar design, insulation, and energy-efficient appliances**
- **For both sectors:**
  - **Controlling standby and idle power consumption; solid-state lighting**
- **Increasing climate change literacy and consumer access to useful information are also components of climate change mitigation strategies**
- **Wide range of ancillary benefits:**
  - **Creation of jobs and business opportunities; increased economic competitiveness and energy security; social welfare benefits for low-income households; reduced infiltration of outdoor pollutants; increased comfort.**

Conclusion 4

- **A variety of policies have been successful:**
  - **Appliance and buildings standards and labeling, building energy codes, pricing measures and financial incentives, etc**
- **The greatest challenge is the development of effective strategies for retrofitting existing buildings**
- **Support from industrialized countries for policy design and implementation in developing countries and EIT could have large impacts**
- **There are many cost-effective technologies available and new options likely to emerge from ongoing RD&D.**

Nonetheless, achieving a lower carbon future will require very significant efforts to enhance programs and policies for energy efficiency in buildings and low-carbon electricity sources, well beyond what is happening today

Thank you for your attention!

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IPCC IV Assessment Report
Chapter 6. Mitigation options in buildings

Supplementary slides

Field	No	Mitigation Technology description	Technology maturation	CO2 reduction potential in Japan (Mt-CO2/year)	CO2 reduction potential in the world (Mt-CO2/year)	Additional CO2 reduction cost (US$/ton-C)
Insulation	1	A structural insulated panel	- Commercialization	11 *3	70 *3	
	2	Evacuated panel				
	3	Transparent insulation material				
Window	4	Advanced double-glazed window	- Commercialization	17 *2		
	5	Vacuum gap window				
	6	Elecrtrochromatic glazing				
	7	Thermochromatic glazing				
	8	Reduce rate of air leakage				
Ventilation	9	Natural ventilation				
	10	Night time ventilation				
	11	Hybrid natural and mechanical ventilation				
	12	Dynamic insulation				
Air conditioning	13	Evaporative cooling				
	14	Underground earth-pipe heating and cooling				
	15	Radiant chilled-ceiling cooling				
	16	Residential air conditioner	- Commercialization	5.7 *1	133 *3	
	17	Commercial air conditioner	- Commercialization	0.6 *1		
	18	Desiccant dehumidification				
	19	Passive solar heating	- Commercialization	2.1 - 1.1 *4		1790 - 3420 *4
	20	Solar thermal energy for heating				

Field	No	Mitigation Technology description	Technology maturation	CO2 reduction potential in Japan (Mt-CO2/year)	CO2 reduction potential in the world (Mt-CO2/year)	Additional CO2 reduction cost (US$/ton-C)
Hot water supply	21	Tank less condensing water heater / Condensing boiler	- Commercialization	0.3 *1 2.4 *4		-4247 *4
	22	CO2 Heat pumps	- Commercialization	3.1 *1		2660 *4
Cogeneration	23	Gas / diesel engine, gas turbine	- Commercialization	11.4 *1		-307 *4
	24	Fuel cells	- Demonstration	3 *1		1680 *4
Lighting	25	T5 and T8 fluorescent lamp and Compact fluorescent lamp(CFL)	- Commercialization	3.4 *1	200 *3	
	26	LED lamp	- Demonstration	3.4 *1		
	27	Day lighting				
Solar energy	28	PV	- Commercialization	2.9 *1		1840 *4
	29	Solar thermal energy for hot water	- Commercialization	2.2 *1		349 *4
Appliances	30	Low flow water fixtures (water-saving shower head and water-efficient dishwasher)	- Commercialization	1.8 *1		
	31	Refrigerator	- Commercialization	1.9 *1	239 *3	
	32	Gas cooking stove	- Commercialization	0.778 *4 1.3 *1		-2060 *4
	33	TV	- Commercialization	2.3 *1		
	34	Video tape recorder	- Commercialization	0.6 *1		
	35	Computer	- Commercialization	4.8 *1		
	36	Router	- Commercialization	2.9 *1		
	37	Microwave oven	- Commercialization	0.03 *1		
	38	Rice cooker	- Commercialization	0.2 *1		

Field	No	Mitigation Technology description	Technology maturation	CO2 reduction potential in Japan (Mt-CO2/year)	CO2 reduction potential in the world (Mt-CO2/year)	Additional CO2 reduction cost (US$/ton-C)
Appliances (continuation)	39	Heated toilet seat	- Commercialization	0.6 *1		
	40	Copy machine / Fax / Printer	- Commercialization	0.07 *1		
	41	Transformer	- Commercialization	0.9 *1 0.3 - 0.2		-719 *4
	42	Automatic vending machine	- Commercialization	1.0 *1 2.8 - 1.5 *4		-1380 *4
Reduction of standby electricity	43	Reduction of standby electricity	- Demonstration	1.5 *1 7.9 - 4.1 *4		-1330 *4
Energy management system	44	BEMS, HEMS	- Demonstration	1.12 *1		2750 - 4360 *4
District heating and cooling	45	District heating and cooling	- Commercialization	1.78 *5		

Note: 1US$=100yen

Sources: Government of Japan, 2005; Tanaka, K. et al.; Nishioka, S. 2001; Sadohara, S. et al., Study on diffusion of district heating and cooling in Japan and its effect on global environment preservation, J. Archit. Plann. Environ. Eng., AIJ, No. 510, 61-67, August 1998